

Real-Time GIOVE Orbit- and Clock-Product Generation with RETICLE

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Introduction

The RETICLE system has been developed and implemented at DLR/GSOC for the estimation of real-time clock corrections of GPS satellites. The system processes dual-frequency observations from a globally distributed network of tracking stations, which transmit their measurements in real-time via the internet. The GPS clock corrections are estimated based on the ultra-rapid predicted satellite orbits from IGS. The RETICLE products are used for near real-time precise orbit determination of LEO-satellites (1). Recently, the system has been extended to also provide real-time clock corrections for the GALILEO test satellites, GIOVE-A and GIOVE-B. The measurements for these satellites stem from the Cooperative Network for GIOVE Observations (CONGO).

Overview of CONGO Network

The CONGO network is a global tracking network, which has been set up by two institutes of the German Aerospace Center (DLR, Oberpfaffenhofen and Neustrelitz, Germany) and the Federal Agency of Cartography and Geodesy (BKG, Frankfurt am Main, Germany). It consists of 11 tracking stations, which are equipped with Septentrio's GeNeRx1, Javad's TRE-G2T-G3TH or Leica's GRX1200+GNSS receivers and track at least GPS and GIOVE-A/-B. All receivers provide observations on the L1 and L2 frequency for GPS and E1 and E5a for GIOVE, however, some stations also support GIOVE's E5b and E6 signals or GPS L5. The measurements are transmitted via NTRIP (2) to a dedicated caster in real-time. The stations are equipped with multi-frequency antennas (mostly Leica's AR25.R3 and Trimble's Zephyr Geodetic II), supporting all frequencies of GPS and GIOVE. Two stations are temporarily equipped with Leica's AX1203+GNSS and will be upgraded to the AR25.R3 in the future. Fig. 1 provides an overview of the station locations and equipment installations (3).

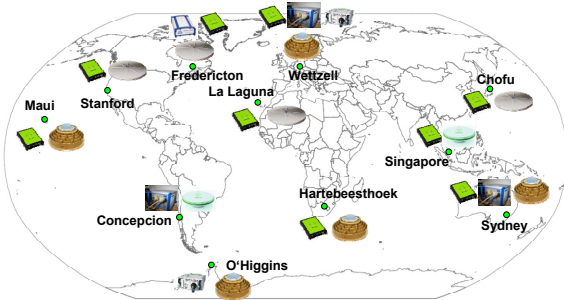


Fig. 1: Overview of Receivers and Antennas in the CONGO Tracking Network

GIOVE Real-Time Processing with RETICLE

The data flow for the real-time processing is depicted in Fig. 2. The data streams of all CONGO stations are recorded into daily Rinex files at the Institute of Astronomical and Physical Geodesy of Technische Universität München (IAPG/TUM, München, Germany). A modified version of the Bernese software is used to compute post-processed orbits and clocks for GIOVE, together with daily estimates of the station-dependent inter-signal/inter-system biases between GPS and GIOVE (4). These precise orbits are predicted over an interval of 48 hours once every day and are used for the real-time clock estimation at DLR's German Space Operations Center (GSOC).

RETICLE retrieves real-time streams of the IGS real-time tracking network together with the CONGO streams and computes a combined GPS+GIOVE clock product. For GPS, the ionosphere-free combination of the C/A or P1 observation and the P2 observation is processed. For GIOVE, the combination is formed from the observations on the E1 and E5a frequency. Depending on the receiver, these observations can be the combined pilot+data or the data-only component.

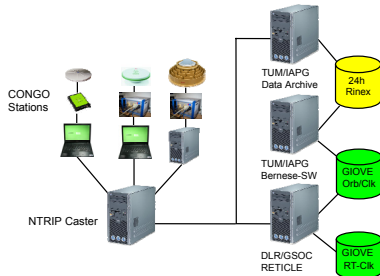


Fig. 2: Data Flow for Real-Time Processing

The system estimates clock offset and drift parameters for all satellites, a clock offset and tropospheric zenith delay for each station as well as the carrier-phase float ambiguities of all tracked satellites. For consistent processing of GPS and GIOVE observations, station- and satellite-dependent inter-signal/inter-system biases must be regarded. The station dependent biases are taken from daily estimates of TUM. In order to avoid an underdetermined system of equations, the bias of the station in Fredericton (Canada) has been deliberately constrained to zero in the daily estimation. The satellite-dependent biases are simply merged with the clock estimates. It should furthermore be noted, that the GIOVE clock estimates are referenced to GPS time. Therefore, users of RETICLE's GIOVE clocks do not have to regard the GIOVE-GPS system time offset, which simplifies mixed GPS/GIOVE processing.

Accuracy of GIOVE Real-Time Orbits and Clocks

Fig. 3 depicts the error of the GIOVE-B orbit predictions with respect to TUM's post-processed final orbit for the time period from May 10-25, 2010. The RMS errors for the radial, along-track and cross-track component are 10 cm, 49 cm and 27 cm, respectively. The predicted orbit is typically available for RETICLE with a latency of 11 hours. The updates of the orbit in the real-time system are clearly visible in the plot.

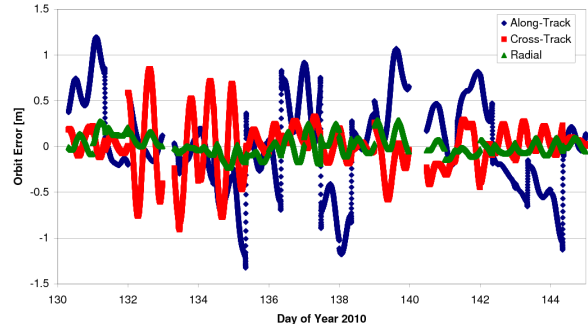


Fig. 3: Errors of orbit predictions for GIOVE-B

Fig. 4 shows the errors of the real-time clock corrections for GIOVE-A and -B estimated by RETICLE compared to TUM's post-processed clock. The errors stay below 0.5 m most of the time, but can rise significantly as on day 134. Due to the low depth-of-coverage of the CONGO network, the GIOVE real-time clock estimation does not reach the high accuracy of the GPS real-time clocks, which exhibit typical errors of less than 10 cm.

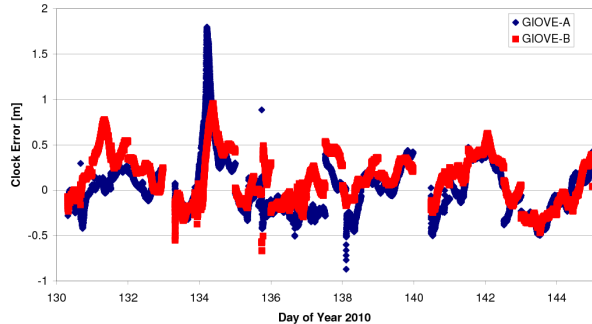


Fig. 4: Errors of real-time clock estimates for GIOVE-A/-B

Conclusions and Future Work

The analysis has shown that the predicted GIOVE orbits reach meter-level accuracy. The resulting clock estimates exhibit errors in the same order of magnitude. The accuracy can be expected to increase with further extensions of the CONGO tracking network. In the future, the real-time clock generation with RETICLE can also be extended to other satellite, like the first GALILEO IOV satellites, COMPASS or the planned QZSS-satellites.

Access to RETICLE's GPS and GIOVE Products

The GPS and GIOVE orbit and clock products are freely available for users in SP3 format via FTP. The products on the FTP-server are updated every 5 minutes and retained for one week.

Server: <ftp.gsoc.dlr.de>, user: `reticle`: password: `getReticle`

For true real-time applications, the products can also be accessed as RTCM3 NTRIP-streams at GSOC's caster <gns.gsoc.dlr.de:2101>. The orbit- and clock-correction data stream is updated every 10 seconds with a latency of ~7 seconds. Furthermore, a data-stream providing the most recent broadcast-ephemerides is available. Access details are provided upon request (andre.hauschild@dlr.de).

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